INTERMOUNTAIN STATION
Central Reference File
No. 0.93

U. S. FOREST SERVICE
RESEARCH NOTE PSW- 40

SOUTHWEST
FOREST & RANGE EXPERIMENT STATION
Berkeley, California — 1964

Predicting Insect-Caused Damage to Douglas-Fir Seed from Samples of Young Cones

ABSTRACT: The percent of Douglas-fir seed destroyed by *Barbara colfaxiana*, *Dioryctria abietella*, *Megastigmus spermotrophus*, and *Contarinia oregonensis* was estimated from cone samples taken in July and in September. The samples were examined by axial-slice and complete dissection. No significant difference was found between the early and late estimates of percent of total insect-damaged seed by either method of examination.

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Surveys of Douglas-fir cones in northwestern California have shown that insect pests often ruin seed crops.[1] In the mid-1950's, poor seed years and heavy insect damage to cones and seeds reduced available stocks of seed for planting. Seed collectors often took any available cones. Many of the cones later proved to be almost devoid of good seeds, thus resulting in a loss of time and money. To find ways of preventing such waste, the Forest Service Experiment Station in Berkeley began research on Douglas-fir cone and seed insects in 1957. One of its objectives was to develop methods of predicting insect-caused damage to Douglas-fir seed from samples of young cones. One way to avoid bad seed is to know in advance how much insects can be expected to reduce the seed yield.

The four insects primarily responsible for losses of Douglas-fir seed--Barbara colfaxiana (Kearf.), Dioryctria abietella (D. & S.), Megastigmus spermotrophus Wachtl, and Contarinia oregonensis Foote--are present and detectable in young cones in mid-July.[2] Methods of estimating damage by at least one of these has been worked out. Johnson and Heikkenen[3], for example, have shown that damage by C. oregonensis can be estimated adequately from axial-slice examinations of the mature cones.

A study was undertaken to determine whether this technique could be used in sampling damage by other species and in sampling

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[1]Stevens, R. E. Surveys of Douglas-fir cone and seed insect damage in northwestern California, 1954-1958. Jour. Forestry 57(12):897-899, illus. 1959.

[2]Koerber, T. W. Insects destructive to the Douglas-fir seed crop in California, a problem analysis. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Tech. Paper 45, 36 pp., illus. 1960.

[3]Johnson, N. E., and Heikkenen, H. J. Damage to the seed of Douglas-fir by the Douglas-fir cone midge. Forest Sci. 4(4):274-282, illus. 1958.

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immature cones. The axial-slice method was tested against complete dissection to obtain data for predicting insect-caused damage to the seed 6 weeks in advance of the expected harvest date.

CONE SAMPLES[4]

Nine plot trees were selected in the summer of 1960 near Orleans, California, on the Six Rivers and Klamath National Forests and on the Hoopa Indian Reservation. Each tree selected was expected to provide 60 cones for examination.

A 30-cone sample was collected from each tree in mid-July and again in early September.[5] Attempts were made to include cones from all portions of the crown. But once cones were collected, they were not segregated as to position in the crown. Each sample was then divided into two equal lots. One lot was examined by the axial-slice method, the other by complete dissection.

CONE EXAMINATIONS

AXIAL SLICE

In the axial-slice method, the cones were cut along the longitudinal axis, using a cone cutter as described by Winjum and Johnson.[6] The number of seeds appearing on one surface of the slice was counted. Each seed was classified as follows: (a) good, (b) hollow, (c) aborted, or (d) damaged by B. colfaxiana, (e) damaged by D. abietella, (f) infested by M. spermotrophus, and (g) damaged by C. oregonensis. The number of seeds in each condition class and the percent of the total were recorded.

COMPLETE DISSECTION

In complete dissection, each cone was trimmed at the base and then dismantled by removing the scales from the axis one at a time. Each seed was counted and evaluated as in the axial-slice method. In both methods, the small scales at the apical and basal ends of the cone, which do not normally produce sound seeds, were excluded.

The same examination procedures were followed for the July cone samples and the ones obtained in September. The data from complete dissections of the September samples were considered the standard estimates of the damage on each tree. These data were used as the controls.

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[4]The author wishes to acknowledge the collaboration of T. W. Koerber, entomologist on the Station's research staff, in selecting the trees for sampling and in making the mid-July cone dissections.

[5]In July one tree provided only 27 and another 29 cones; in September a third tree had only 25 cones.

[6]Winjum, J. K., and Johnson, N. E. A modified knife cone cutter for Douglas-fir seed studies. Jour. Forestry 58(6): 487-488, illus. 1960.

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RESULTS

To compare samples, the data were grouped into two classes: good seed and bad seed. Each class was expressed as a number and percentage of the total (tables 1 and 2). Table 3 shows the difference between predicted and actual seed damage, based upon analysis of variance of the data for all trees.

1. On each of the nine trees, the estimated percent of bad seed obtained by the axial-slice method of cone examination was not significantly different (based upon X^2 analysis at the 95 percent level of confidence) from the estimates obtained by complete dissection for samples taken at the same time.

2. In half the cases, the mid-July estimates of percent bad seed by both methods were significantly different from the corresponding estimates made in September. Although significant, these differences were small--none exceeding 2.5 percent.

3. In most cases, the estimated percent of seed destroyed--by individual species and by all species combined--as estimated by both methods of examination in mid-July, was significantly different from corresponding estimates made in September.

4. When data for all trees were combined and subjected to analysis of variance, no significant difference between the July axial-slice estimates and the September dissection estimates was found except for D. abietella damage. Therefore, this analysis supports the conclusions of Johnson and Heikkenen that the axial-slice examination method is suitable for obtaining estimates of damage by C. oregonensis.

DISCUSSION

Since the cones on all trees had suffered extremely heavy damage, it was impossible to ascertain whether the axial slice examination method would be adequate to estimate light or medium damage. This method, however, is suitable for the detection of heavy damage and the prediction of a correspondingly high seed yield reduction when hollow and aborted seeds are included with insect damage in a class termed "bad seed." Its suitability under these conditions may be due to the fact that if seed is almost completely destroyed in early summer, it will most certainly not improve by the fall collection date, so that almost any means of assessing heavy damage may be sufficient.

Several complicating factors were encountered. First, the aborted seeds on the axial slice of badly damaged cones could not be detected. This introduces a difference in what is sampled by the two methods, and affects the total seed counts and the percentages in each condition class. Because the statistical analysis is based on the percentages, this error may best be avoided by disregarding aborted seeds in both methods.

Table 1. Estimates of good and damaged seed in 530 Douglas-fir cones from nine trees, by method and time of sampling

Kind of seed	Examination method	Total number	Number per cone Mean	Std. dev.	Percent of total sample
JULY SAMPLING					
Good:					
	Axial slice	75	0.56	0.98	3.50
	Dissection	278	2.11	3.09	3.97
Bad:					
Insect damaged	Axial slice	1,760	13.23	6.51	82.17
	Dissection	4,329	32.80	16.11	61.75
Hollow	Axial slice	307	2.31	2.17	14.33
	Dissection	986	7.47	7.34	14.06
Aborted	Axial slice	--	--	--	--
	Dissection	1,418	10.74	7.96	20.22
Subtotal	Axial slice	2,067	15.54	5.53	96.50
	Dissection	6,733	51.01	9.87	96.03
Total	Axial slice	2,142	16.10	5.16	100
	Dissection	7,011	53.12	9.25	100
SEPTEMBER SAMPLING					
Good:					
	Axial slice	32	0.24	0.62	1.52
	Dissection	125	.94	1.81	1.59
Bad:					
Insect damaged	Axial slice	1,712	12.97	3.92	81.45
	Dissection	6,007	45.16	12.13	76.91
Hollow	Axial slice	358	2.71	2.22	17.03
	Dissection	643	4.83	5.46	8.23
Aborted	Axial slice	--	--	--	--
	Dissection	1,035	7.78	7.86	13.25
Subtotal	Axial slice	2,070	15.68	3.00	98.48
	Dissection	7,685	57.78	8.87	98.39
Total	Axial slice	2,102	15.92	2.92	100
	Dissection	7,810	58.71	9.03	100

Table 2. Estimates of insect-damaged seed in 530 Douglas-fir cones from nine trees, by method and time of sampling

Insect	Examination method	Total number	Number per cone Mean	Std. dev.	Percent of total sample
JULY SAMPLING					
B. colfaxiana	Axial slice	692	5.20	5.60	32.31
	Dissection	1,792	13.58	14.78	25.56
D. abietella	Axial slice	83	.62	2.36	3.87
	Dissection	365	2.76	6.71	5.21
M. spermotrophus	Axial slice	106	.80	1.18	4.95
	Dissection	306	2.32	3.54	4.36
C. oregonensis	Axial slice	879	6.61	5.34	41.04
	Dissection	1,866	14.14	13.75	26.62
Total	Axial slice	1,760	13.23	6.51	82.17
	Dissection	4,329	32.80	16.11	61.74
SEPTEMBER SAMPLING					
B. colfaxiana	Axial slice	754	5.71	3.90	35.87
	Dissection	2,177	16.34	14.25	27.87
D. abietella	Axial slice	273	2.07	3.06	12.99
	Dissection	941	7.08	11.43	12.05
M. spermotrophus	Axial slice	41	.31	.67	1.95
	Dissection	178	1.34	2.48	2.28
C. oregonensis	Axial slice	644	4.88	3.73	30.64
	Dissection	2,711	20.38	14.05	34.71
Total	Axial slice	1,712	12.97	3.92	81.45
	Dissection	6,007	45.16	12.13	76.91

Table 3. Predicted and actual present seed damage, by cause for all trees combined

Cause of damage	Percent of seed damaged	
	Predicted[1]	Actual[2]
Insect:		
B. colfaxiana	32.31	27.87
D. abietella	3.87*	12.05
M. spermotrophus	4.95	2.28
C. oregonensis	41.04	34.71
Subtotal	82.17	76.91
Hollow	14.33	8.23
Aborted	--	13.25
Total bad	96.50	98.39

[1] *July axial-slice estimate for all trees.*
[2] *September dissection estimate for all trees.*
**Difference significant at the 5 percent level.*

Second, seed damage caused by both B. colfaxiana and D. abietella could be accurately recognized on the axial slice as the damage of moth larvae, but assignment of the damage to a particular moth was difficult. D. abietella usually occupies a silk-lined tube, but this is not always apparent without probing below the surface of the slice; nor is the tube always present. The accurate recognition of M. spermotrophus and C. oregonensis damage by either method of examination was no problem.

A third problem, which may be important where light and medium damage are found in mid-July, is the continued feeding of D. abietella during late summer. This is the probable cause of the one case of significant difference between the July and September estimates of percent seed damage for all trees combined. If cones are only lightly damaged by the other species of insects at the time sampled, Dioryctria larvae might cause enough additional damage to make undesirable the collection of the cones for seed extraction.

Finally, it was concluded, from the difficulty encountered in assessing all seeds in heavily damaged cones, that it would be better to count only the good seeds. These stand out distinctly. To estimate several broad classes of damage suffered by Douglas-fir cones, we suggest the following procedure: Use some average value for the expected number of seeds to be found on a damage-free slice. Then establish limits to several damage classes expressed in numbers of good seeds; e.g., assuming an average of 18 seeds per undamaged slice, then 12 to 18 good seeds = light damage, 6 to 11 good seeds =

moderate damage, and 0 to 5 good seeds = heavy damage. This procedure would probably be adequate when used in the field by personnel interested in collecting seed for reforestation purposes.

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